Hiroaki Kobayashi
Tokyo University of Mercantile Marine Japan

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MARINE CASUALTY ANALYSIS USING SHIP-HANDLING SIMULATOR

It is said that more than 80% of the cause, for marine casualty are human according to the accident analysis. In this paper, we discuss the relation between the causes of accident and human error. Human errors, that cause the marine casualties are divided into the following two categories;

Category 1: Operator cannot accomplish the standard function

Category 2: Operator accomplishes the standard function

In the case of first category, the doze, drunk, mental and physical fatigue and the lack skill are corresponded. Usually, the human error being treated as the causes of accidents are not divided into the categories mentioned above. The causes of accidents in two categories are treated as human error in a lump. For the prevention of accidents, the countermeasures for each category differ from each other. The countermeasures for the prevention of accidents based on the category 1 are education and enforcement. But when the operator who belongs to category 2 occur the accident, the countermeasures corresponding to category 1 are not proper. Because he have sufficient ability and normal condition, it is not reasonable way to educate and enforce for getting the standard skill. There must be more rational countermeasures for preventing the accident in category 2.
It is important to clear the causes of accident which occurred relating to the category 2. But the research is usually very difficult because of operator acting the normal handling. As a result, proper countermeasures are not applied. Generally speaking, most of causes of vehicle accidents such as aircraft, vessel and car are judged as human error. In case of vehicle accidents, most of the operators are pursued their responsibility because operators decide the final action which was a direct cause of the accident, in spit of the action based on the normal decision which are commonly made by standard operators.
In this paper, the accidents in category 2 are discussed in order to clarify the methods how to recognize the structure of this accident and the methods of researching the causes and countermeasures.

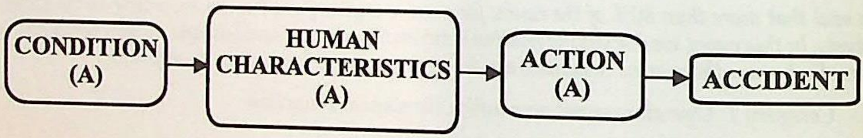
1. THE RELATION BETWEEN THE ACCIDENTS AND HUMAN ERROR

When the standard operator made the action which is the same as actions made by standard able operators, then the accidents occurred. Is it proper to judge his action human error? If we accept it as a human error, can we point him that he did not his responsibility? From the view point of preventing accidents, it is easy to estimate that the other standard able operator will do the same action in the face of the same situations and the accident willoccur. In order to prevent the same accidents, it is necessary to find the condition in which standard able human acts normally handling without accidents.

The human's action would be the same under the same condition because of education and enforcement. In order to discuss the relation between the accidents and human error, we assume that the human mentioned above is having the standard ability and the giving conditions are ship's characteristic, rules of road, traffic condition and natural environment. The relations among the conditions, accident and the human error corresponding to category 2 are discussed. 4 kinds of relation are proposed as follows;

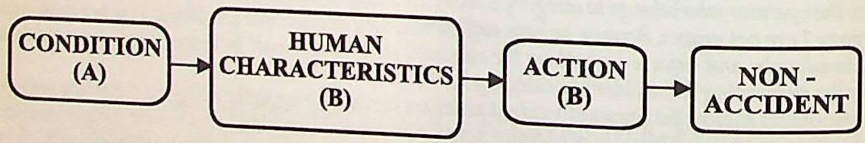
Case 1.

The accident occurred and is caused by human's action type A which is induced by condition type A. The human characteristics (A) generates the action (A) caused by condition (A). The accidents caused by human error in category 2 are belonging to this case.



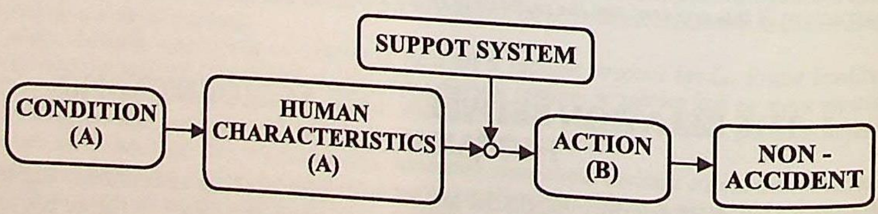
Case 2.

In this case, the human characteristics differ from type A to type B by something to be improved. Therefore this human characteristics generate the action (B) corresponding to the condition (A). The accident does not occurre because of human's action type B.



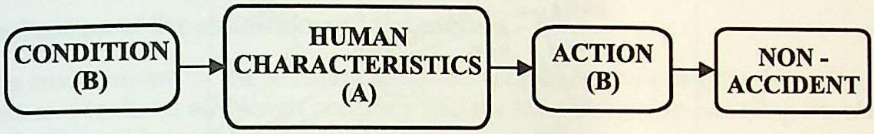
Case 3.

In this case, the human characteristics are still of type (A). The action is (B) by the effect of the support system and the accident will not occur in spite of condition (A) and human characteristics (A).



Case 4.

The accident does not occurre because of human's action (B). Though the human characteristics is (A), Human action differs from (A) to (B) because of condition changing from (A) to (B).



From this concept, the accidents will be prevented by changing from Case 1 to Case 2 of Case 3 or Case 4. In order to change the human action from (A) to (B), three patterns can be considered. The first one is to improve the human characteristics by special training and education. These countermeasures correspond to Case 2. The second one is not to change the human characteristics. The action would be changed by support system which improves the human characteristics virtually. A new control apparatus for handling is one of these support systems. These countermeasures correspond to Case 3. In the case of Case 4, the condition is changed by applying new traffic rules, and new types of ship etc.

In order to prevent the accidents in category 2, the countermeasures mentioned above are proper methods. The concrete methods depend on the causes of accidents. So it is important to clarify the causes of accidents. In the following section of this paper, one example of the accidents analysis, that were carried out for studying the causes of accidents using ship handling simulator, are described.

2. COLLISION BETWEEN YUYO-MARU AND PACIFIC ARES

On 9th Nov. 1974, Yuyo-maru proceeded to north bound in Nakanose fairway in Tokyo bay in Japan, Visibility was 2.0 miles. Yuyo-maru was LPG tanker, 43,724 GT, 227 m in length and 35.8 m in width. Nakanose strait is one way fairway. Pacific Ares proceeded to west bound from Kisarazu harbor. Pacific Ares was iron material carrier, 10,875 GT, 154 m in length and 22.2 m in width. The pilot on Pacific Ares (being abbreviated as P.A.) left ship after informing that Yuyo-maru (being abbreviated as Y. maru is coming from port side through Nakanose fairway. Master of Y-maru recognized P.A. at the distance of 2 miles and started to decelerate of her speed at the point of 1389 m on this side of the encountering point. P.A. proceeded without avoiding action until the collision. They made collision at the encountering position. Fig. 1 shows the process of two ships situation. By this accident all the persons, on P.A. died and 5 person on Y. maru died. This accident cause made to people an extreme shock. Fig. 2 shows the newspaper informing this accident. After the collision occurred, Y. maru and P.A. were in flames. Y. maru was in flames for 20 days. Finally, she was towed out of the Tokyo Bay and sank by bombing.

3. SIMULATOR STUDIES

In this section, the contents of simulator studies to analyze the causes of accident are shown. In order to simulate the accident condition and the ship's characteristics, we have examined the following documents and data proposed by the Japanese Maritime Court.

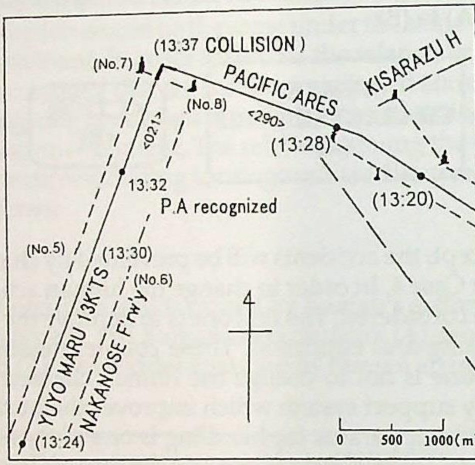


Fig. 1 The process of collision between Y. maru and P.A.

—6 Dead, 28 Missing in Fire—

LPG Tanker, Freighter Collide in Tokyo Bay

YOKOHAMA—All 29 crewmen aboard a Liberian freighter were feared to have been killed in a fire triggered by a collision Saturday afternoon with a capacity-loaded Japanese liquefied petroleum gas (LPG) tanker in Tokyo Bay.

Six persons were found dead. They were five crewmen of the freighter and one crewman of the LPG tanker, police said. Twenty-eight others were reported missing as of late Saturday night.

Seven of the survivors suffered burns.

According to reports, all the crew members of the Liberian freighter are Chinese. It is captained by Lo Yao Nan, 47.

The 43,723-ton tanker Yuyo Maru No. 10, owned by Yuyo Kaiun Co., Tokyo, and the 14,000-ton freighter Pacific Ares collided near the No. 7 buoy in the Nakanose fairway about 10 kilometers east of Honmoku, Yokohama, at about 1:40 p.m.

Both vessels were set ablaze.

At 4:30 p.m., an explosion crashed into the starboard bow of the Yuyo Maru No. 10.

The collision triggered a fire near the bow of the tanker and the freighter caught fire, too.

Then the crew members of the tanker abandoned their ship.

The captain and boats wain left the ship after all the rest of the crew left the ship.

Yoshikatsu Toru, 21, a deckhand of the tanker who was hospitalized in Yokohama, said that while he was resting on the afterdeck, there was a booming sound and a blaze shot up from the bow immediately afterward.

He immediately jumped overboard and swam in a sea covered with naphtha for about two hours until he was rescued by a patrol boat, the

A fireboat battles a blaze aboard the liquefied petroleum gas tanker Yuyo Maru No. 10 in Tokyo Bay off Honmoku, Yokohama, Saturday following a collision with the Liberian freighter Pacific Ares.

Fig. 2 Newspaper informing the collision accidents

Estimation of ship's maneuvering characteristics

The characteristics of Y. maru and P.A. were estimated based on the following data and simulated using mathematical model which could estimate the ship's motion with high accuracy.

(1) The results of trial test.
(2) The table of principal dimensions
(3) The numerical estimation for speed control
(4) Others

Realization of the condition and the process

The environment of the accident situation was examined using the following the data and realized with high accuracy and realistically by ship handling simulator at the Tokyo Univ. of Mercantile Marine.

(1) Arrangement of sea buoy
(2) visibility
(3) Both ship's initial position course and speeds
(4) Others

Contents of simulator studies

In this studies, as the behavior of the operator on P.A. could not be known, the behavior of the master on Y. maru was discussed. The objects of simulator studies are the action of the master on Y. maru and the motion characteristics of Y. maru. In order to clarify the causes of accident, the effects of the following factors are examined:

(1) Timing to start avoiding the action.
(2) Methods for avoiding collision.
(3) Rules of road.
(4) Ship's maneuvering characteristics.

4. ANALYSIS

Collision avoiding timing

The time to start the avoiding action is a very important factor which decides, the accomplishment of the collision avoidance or not. The master of Y. maru recognized P.A. at about 2,700 m on this side of encountering point and start avoiding action at 1,389 m. The time to be considered for discussing the effect on the collision avoiding can be set at the position between the point of 2,700 m and the point of 1,389 m on this side of encountering point.

(1) Start to maneuver at the point of 1,389 m

Initial position of Y. maru was 1389 m on this side of encountering point where the master of Y. maru started to avoid the action. This point is called A.T. in the following sentence. 4 skilled masters started to maneuver in Nakanose fairway and made action to avoid collision at the time when they considered to have to do it. The contents of avoiding action were restricted, as only speed control they was applied for avoiding collision by master on Y. maru.

Fig. 3 shows the time history of engine control mode. Every master began the decelerating to avoid collision immediately just after the maneuvering had started. As the results of avoiding actions, all of their objective could not be accomplished and collision occurred in every case.

(2) Start to maneuver at the point of 2,700 m

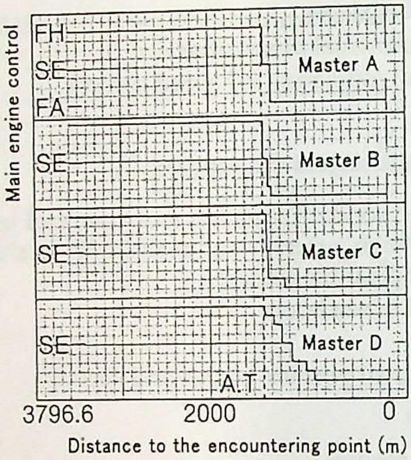


Fig. 3 The time history of engine control started from A.T.

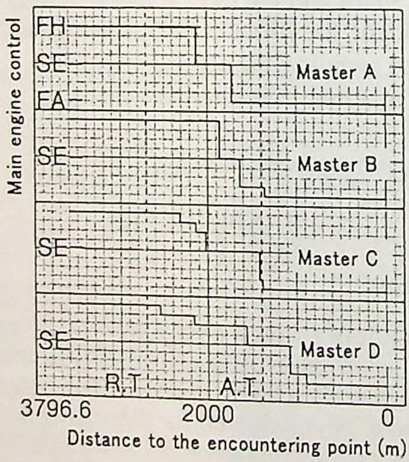


Fig. 4 The time history of engine control started from R.T.

Assumed position corresponded to the position where the master of Y. maru recognized P.A.. This point is called A.T. in the following sentence. 4 skilled masters also handled and started to maneuver in Nakanose fairway and made action to avoid collision at the time when they considered to have to do it. The contents of avoiding action were restricted, as only speed control was applied for avoiding collision by master on Y. maru.

Fig. 4 shows the time history of engine control mode. In this case, all of them did not start to handle the avoiding action immediately. They kept her motion for a moment. Each master started to decelerate her speed at the time when he considered the necessity to avoid collision by himself, they were not at the same timing. When they navigated out of fairway, they reformed the avoiding action earlier in this encountering situation. It is the particular handling characteristics in fairway why they didn't make avoiding action earlier. Anyway, all the masters in this simulator studies avoided the collision. But the distance at the closest point of approach was very small.

Collision avoiding methods

In the previous section, the contents of avoiding action applied only speed control that was applied for avoiding collision by master on Y. maru. Now we cannot estimate why master on Y. maru did not change her course by steering the rudder for avoiding the collision. We tried to confirm the effectiveness of changing her course. Two cases were applied, one was to avoid using rudder control, the other was to avoid rudder and speed control.

(1) Applying the rudder control to avoid collision

4 skilled masters started to maneuver from position of 1389 m on this side of encountering point in Nakanose fairway and made action to avoid collision at the time when they considered to have to doit. The contents of avoiding action were restricted, as only heading control was applied.

The distance at the closest point of approach (DCPA) caused by heading control for avoiding collision were examined, based on the numerical simulation. The results of simulation are shown in Fig. 5. The contents of avoiding maneuver is to carry out the parallel shift maneuver shown in Fig. 6 because of navigating in the fairway. The DCPA is 320 m when the avoiding action started at the point of A.T.. The relation between the starting point and DCPA are shown in Fig. 5.

Table 1 shows the DCPA which are obtained by simulator studies. All masters could avoid the collision.

(2) Applying the rudder and speed control to avoid collision

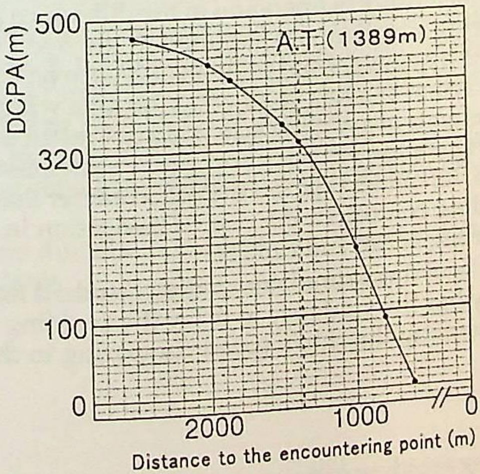


Fig. 5 The relation between DCPA and starting point using heading control.

4 skilled masters also started to maneuver from position of 1389 m on this side of encountering point in Nakanose fairway and made action to avoid collision

at the time when they considered to have to do it. The contents of avoiding action were not restricted. All masters could avoid the collision.

Table 1 shows DCPA as the results of simulator studies in this section. The DCPA in case of avoiding collision using speed control only from A.T. were 0.0. m; collision occurred. The DCPA in case of avoiding collision using heading control only or heading and speed control from A.T were over 129.0 m; collision did not occur.

By the results of this section, it is said that the heading control is an effective measure to avoid collision. But most of the masters, cannot apply these characteristics effectively in fairway. Three of the masters who operated in simulator studies obtained DCPA under 200 m.

Table 1 DCPA concerning the control methods

	DCPA (m)		
	Speed	Heading	Speed/Heading
A	0.0	340.9	356.0
B	0.0	174.3	154.5
C	0.0	172.2	188.5
D	0.0	164.0	129.0

Compulsory navigation in fairway

The master on Y. maru made the action to avoid collision by speed control, and not by other control. We estimate that his action was affected by navigating in the fairway, the human characteristics of operation in the difference area were examined. The same encountering situation was assumed in the open water area. 4 skilled masters also started to maneuver from position of 2700 m on this side of encountering point and made action to avoid collision at the time when they considered to have to do it. The contents of avoiding action are not restricted. All masters could avoid the collision. Fig. 7 shows the position where each master started the action to avoid the collision. All masters started the action earlier than in the fairway and they used only heading control. In the case of navigation in fairway, half of the masters controlled using speed and rudder.

From the results of these simulator studies, standard human operator navigating in the fairway has the tendency to delay the avoiding action and to apply the control by decelerating the ship's speed comparing to the navigation in the open water area.

Maneuverability

The timing for starting avoiding collision strongly relates, to the ship maneuvering characteristics such as decelerating and altering course. Y. maru was a large who usually tanker changes, the motion very slowly. We tried to discuss the effect of difference of maneuverability. The container ship was applied to discuss the difference between Y. maru and another ships that have better maneuvering characteristics.

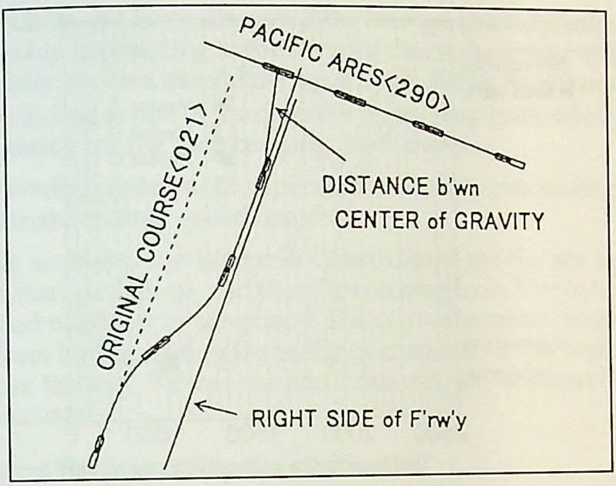


Fig. 6 The contents of avoiding action using heading control.

The assumed position corresponded to the position where master of Y. maru recognized P.A.. 4 skilled master also handled and started to maneuver in Nakanose fairway and made action to avoid collision at the time when they considered to have to do it. The contents of avoiding action were restricted, as only speed control was applied for avoiding collision by master on Y. maru. In this case, all of them did not start to handle the avoiding action immediately. They kept her in motion for a moment. Each master started to decelerate her speed at the time when he considered the need to avoid collision by himself, they were not at the same timing. Anyway, all masters in this simulator studies avoided the collision.

Fig. 8 shows the relation between the DCPA and starting point for decelerating her speed concerning Y. maru and the container ship respectively. The starting position of the container ship was closer than the one of Y. maru. In spite of a closer point, DCPA were greater than DCPA of Y. maru.

Furthermore, by numerical simulation based on the maneuvering characteristics of a container ship, it is possible to avoid collision when the speed control started from A.T.

From the above discussion, the maneuvering characteristics were strongly effected in this accidents.

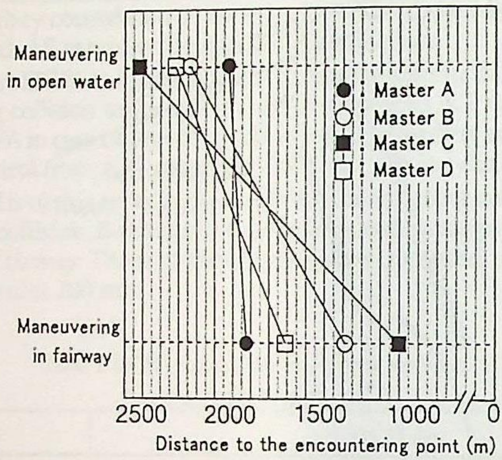


Fig. 7 The starting point of avoiding action in the fairway and open water

DISCUSSION

Collision between Y. maru and P.A.

The water area near the exit of the fairway is a complicated place because of the switching of two traffic rules. The ship proceeding in the fairway must keep her track in the fairway and can proceed without avoiding the ship which crosses the fairway. The ship intending to cross the fairway has, to avoid the ship proceeding in the fairway. When two ships encounter at the water area near the exit of the fairway, what is the best way to avoid collision? In the case discussed in this paper, the master on Y. maru recognized that P.A. was the ship crossing the fairway and expected that P.A. would avoid Y. maru. The operator on P.A. died, we cannot know what he thought of this situation.

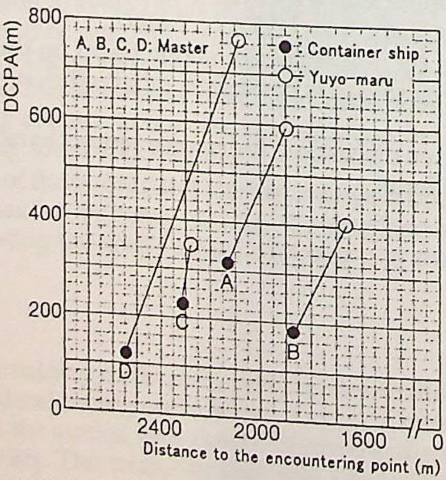


Fig. 8 The relation between DCPA and starting point of avoiding action concerning Yuyo maru and a container ship.

In this section, we have discussed the human characteristics of who is the operator on the ship proceeding in the fairway, that is the master of Y. maru. By the results of simulator studies, the following characteristics have been obtained:

(1) The avoiding action of the operator on the ship proceeding in the fairway tends to delay for the ship crossing the fairway.

(2) The avoiding action of the operator on the ship proceeding in the fairway tends to make mainly speed control

After this accident, the Japanese Coast Guard set the sea buoy on the extended line of Kisarazu fairway and the ships coming from Kisarazu fairway are required to proceed north of the new buoy. These countermeasures are intended for ships coming from both direction that will not encounter at the water area near the exit of Nakanose fairway. By this countermeasures, the accident like an this case will not have occured.

Countermeasures for preventing the accidents.

We discussed the relation between the accidents and human error in section 1 of this paper. The accident discussing in this paper was judged as caused by human error. Most of the skilled masters handled the same action as the master on Y. maru. The same accidents will occurr in case of not making effective countermeasures. The causes of this accident should be judged as category 2 in section 1. From these results, it is well known that the same situation often appear in the area near the exit of the fairway such as Nakanose fairway.

When we discuss the content of the countermeasure for this accidents, the countermeasure by the Japanese Coast Guard is the proper one, because no accidents like the accidents of Y. maru have occurred.

It is always said that the causes of accident and countermeasures to prevent accidents that belong to Category 2 are found difficult. The causes and measures of accidents in Category 2 are discussed referring to the Y. maru accidents. The countermeasures by J.C.G, setting new buoy, correspond to the Case 4. The master, with standard skill, maneuvers in Nakanose fairway safely without any support system and because of the change of the traffic rules, the conditions have been changed.

Meanwhile, the handling by an excellent skilled operator, such as the pilot, did not make the accidents, this situation correspond to Case. 2. The support system which gives inform the proper time to start this avoiding action and the proper way of avoiding corresponds to Case 3.

The accidents do not occurr by single error or event, they always occurred by several events that happen continuously in a chain. As the causes of accidents are clarified respectively, the methods to remove the causes are found out. It is not necessary to remove all the causes, it is important to cut the error chains. The best method for selecting the measure depends on the kind of accidents and efficiency.

The concept concerning the structure of accident by human error in Category 2 is necessary and useful.

6. CONCLUSION

The relation between the accidents and Human error are very important. Human error causing the accidents are divided into 2 categories shown in section 1. The human error in category 2 are mainly discussed because the countermeasures for Category 1 are simple because these causes are the lack of normal human abilities. In the case of category 1, the education must be done.

In the process of accidents belonging to category 2, it is necessary to discuss the relation among the condition, human characteristics, human action and accidents, In order to prevent the accidents caused by human error in category 2, the understanding of the process is very important. Three concepts for preventing accidents are proposed. The necessity and effectiveness of these concepts are confirmed through analyzing the great accidents occurred in Japan. The ship handling simulator is very useful for analyzing the causes of marine casualty and human characteristics. Through the simulator studies, the countermeasures can be suggested.

Many accidents that were judged as the results of human error have occurred all over the world. Some of them were better understood, if they belonged to category 2. In this case, the countermeasure pointing the loss of human ability are not the complete ways. This measure means that the same accidents will occur again by the same error by standard operators. To say again, in these cases, the countermeasures that are indicated in section 1 of this paper are necessary. The unsuitable measures have been used in many cases up to now.

Sažetak

ISTRAŽIVANJE POMORSKIH NESREĆA BRODSKIM SIMULATOROM

Govori se da je ljudski faktor uzrok 80 posto pomorskih nesreća, a to proizlazi i iz analize tih nesreća. U ovom se radu raspravlja o odnosu između uzroka nesreća i ljudskog faktora. Ljudski faktor, kao uzrok pomorskih nesreća, može se podijeliti u dvije kategorije: 1. kategorija: čovjek ne može obaviti standardne zadatke; 2. kategorija: čovjek obavlja standardne zadatke.
U prvu se kategoriju može ubrojiti i dremuckanje, pijanstvo, mentalni i fizički umor i nedostatak stručnosti. Najčešće se uzroci nesreća, podijeljeni u dvije kategorije, tretiraju zajednički kao ljudski faktor, iako se ljudski faktor, koji se smatra uzrokom nesreće, ne dijeli u prije spomenute kategorije. Protumjere u svrhu sprječavanja nesreća, razlikuju se za svaku kategoriju. Protumjere u svrhu sprječavanja nesreća izazvanih na osnovi prve kategorije jesu obrazovanje i njegova prisilna primjena. Ali kada čovjek, koji pripada drugoj kategoriji, prouzrokuje nesreću, protumjere koje se primjenjuju za prvu kategoriju, tu ne vrijede. I to zbog toga što je čovjek već stručan i radi u uobičajenim uvjetima, pa nije logično da se obrazuje i da ga se prisili da stekne standardnu stručnost. Moraju, dakle, postojati razumne protumjere za sprječavanje nesreća navedenih u drugoj kategoriji.
Važno je razjasniti uzroke nesreće koji se javljaju u drugoj kategoriji. Takvo je istraživanje obično teško provesti zbog toga što čovjek radi pod uobičajenim okolnostima. Kao rezultat toga, prave se protumjere ne mogu primijeniti. Općenito govoreći, većini automobilskih i avionskih nesreća, te nesreća na moru, uzrok je upravo ljudski faktor. Kad je riječ o automobilskim nesrećama, većina vozača smatra se odgovornim budući da su upravo oni donijeli konačnu odluku koja je bila izravan uzrok nesreće, usprkos potezu koji se temelji na normalnoj odluci koju uvijek standardno donosi čovjek.
U ovom se radu raspravljalo o nesrećama koje spadaju u druge kategorije, kako bi se razjasnile metode pomoću kojih bi se otkrila struktura tih nesreća kao i metoda istraživanja uzroka i protumjera.